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AIR POLLUTION POTENTIAL IN
ARIZONA.

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Air Pollution Potential in Arizona

by

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This supplementary report consists of results of two examples of air quality calculations. The first concerns the concentration of a non-reactive pollutant, carbon monoxide, adjacent to a highway and the second the effect of nitrogen dioxide on visibility. In each case a typical example is presented corresponding to average conditions in northern Arizona.

The results show that carbon monoxide concentrations are high only in the immediate vicinity of the highway and the program HIWAY gives a reasonable extimate of the level. Discoloration of the horizon as a result of NO_2 emissions from an uncontrolled coal fired power plant would be visible over long distances. Reductions in visibility would be evident only along the plume line for a short distance from the stack. Visibility is more a function of particulate emission which is not discussed in this report.

Isolated traffic -- Air Pollution

The computer program, HIWAY[1], can be used to predict air quality levels of non-reactive pollutants generated by traffic on the highway. For an "at-grade" highway, each lane of traffic is treated as a straight, continuous, finite line source with a uniform emission rate. Pollutants downwind from a line source are found by a numerical integration along the line source of a simple Gaussian point-source plume.

The location of the highway is specified by the co-ordinates at the centerline (from edge to edge) of the highway (point 1 and 2), as shown in Figure 1 for a four lane highway. The ordering of the lanes is from left to right when one looks from point 1 to point 2. One lane or any even number of lanes from 2 to 24 can be used in this program.

For an example of a highway leading to a recreational area, we set 2 lanes running south to north with a length of 10 km. Placing the centerline of the highway to coincide with the north-south axis, the co-ordinates are -5.000, 0.000 for point 1, and 5.000, 0.000 for point 2. Emission height is chosen to be 0.0 meters (at ground level). The width of the highway (from edge to edge) is 13.0 meters and there is no center strip (width of center strip = 0.0 meter). The wind is coming from the west (270°) with a speed of either 1 m/s or 3 m/s. The stability classes being considered are B (2) corresponding to a mixing height of 1000 meters and F (6) corresponding to a mixing height of 100 meters. With a traffic volume of 5000 vehicle/hr. (going from north to south only), the emission rates are calculated to be 0.216×10^{-1} g/sec-meter for a vehicle speed of 55 mph (emission factor, 25 g/mile), and 0.431×10^{-1} g/sec-meter for a vehicle speed of 20 mph (emission factor, 50 g/mile).

The concentrations of pollutant east of the center of the highway are calculated and graphed as shown in Figures 2 to 5. The results show that levels above air-quality standards are exceeded only at locations within 100 meters of the highway. Comparisons of the HIWAY model with actual carbon monoxide samples near a freeway in Phoenix showed that HIWAY predicted higher concentrations than observed more often then lower concentrations[2].

Details of the program and its use are given in Reference 1.

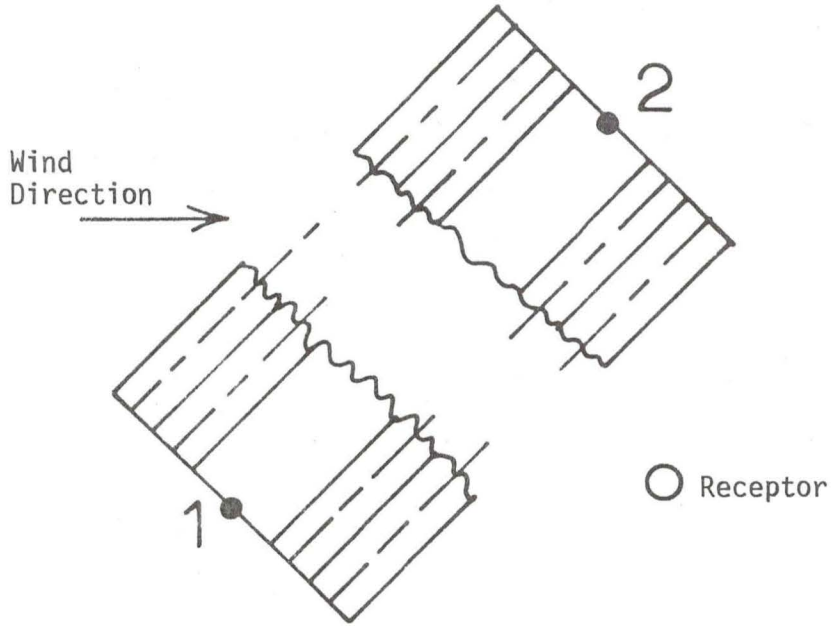

Fig. 1. Overhead view of Geometry of at-grade highway showing two lanes of line sources in each direction separated by a medium.

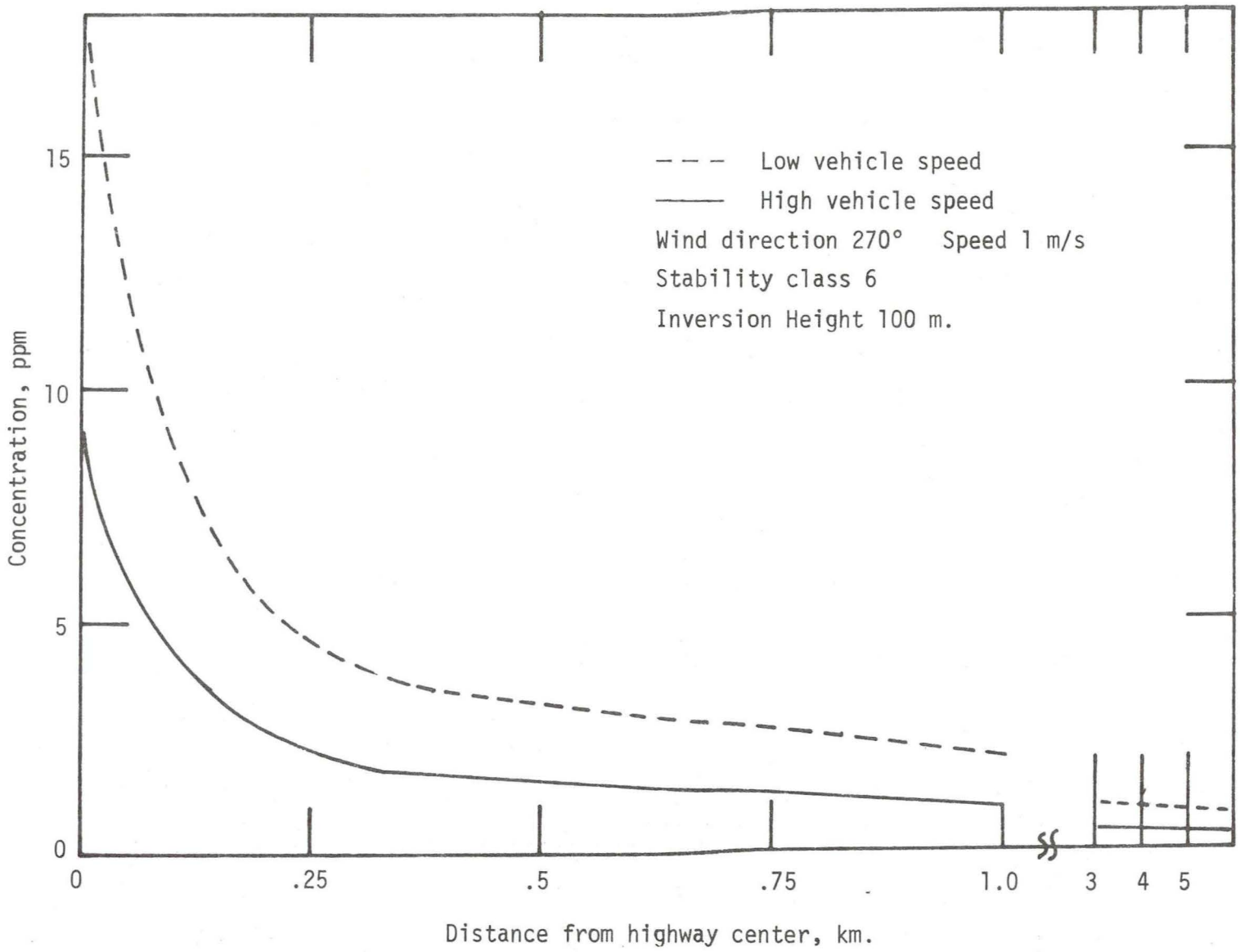

Fig. 2. Program HIWAY results for low wind speed, low inversion height case, one traffic lane.

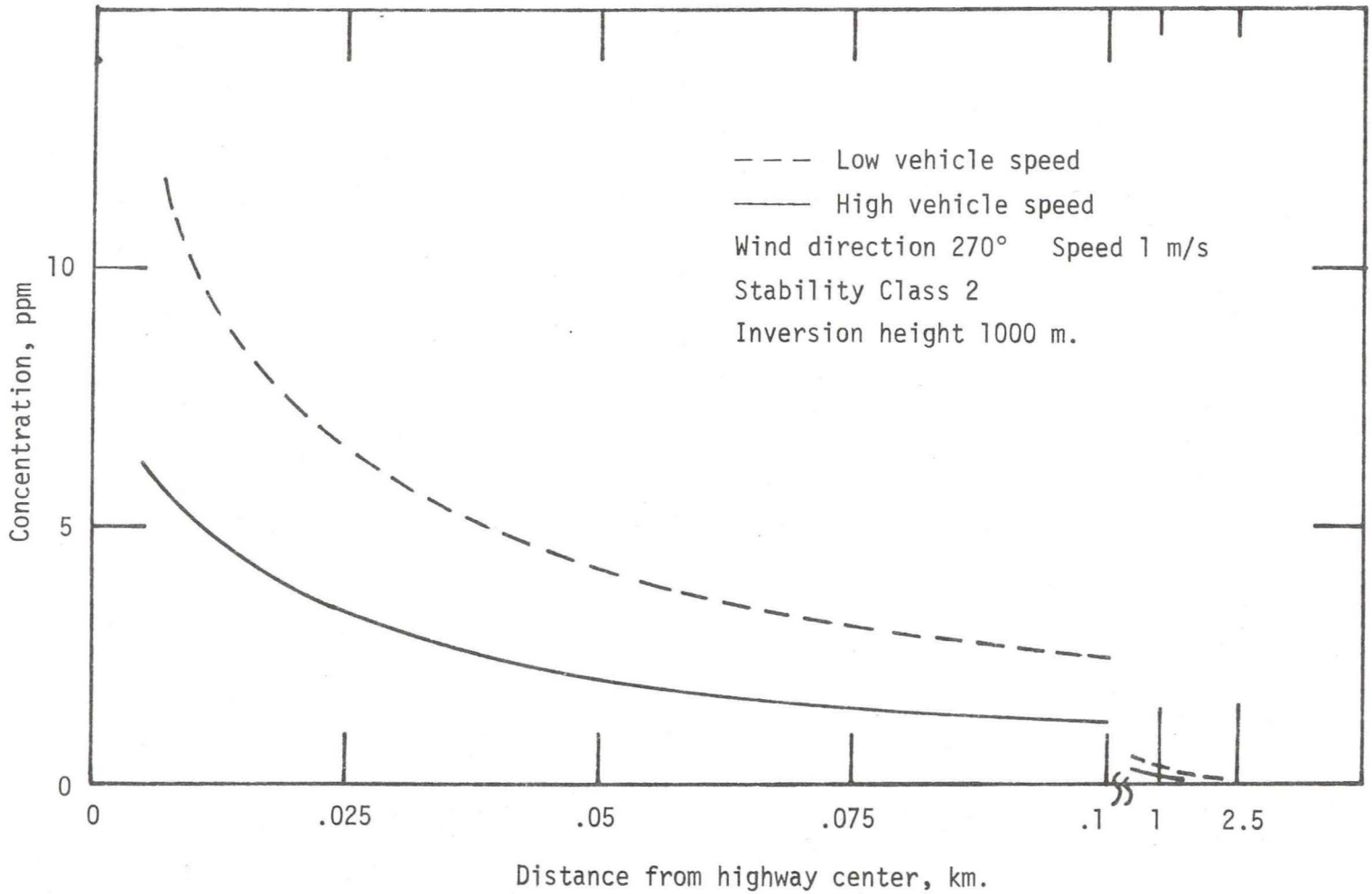

Fig. 3. Program HIWAY results for low wind speed, high inversion height case, one traffic lane.

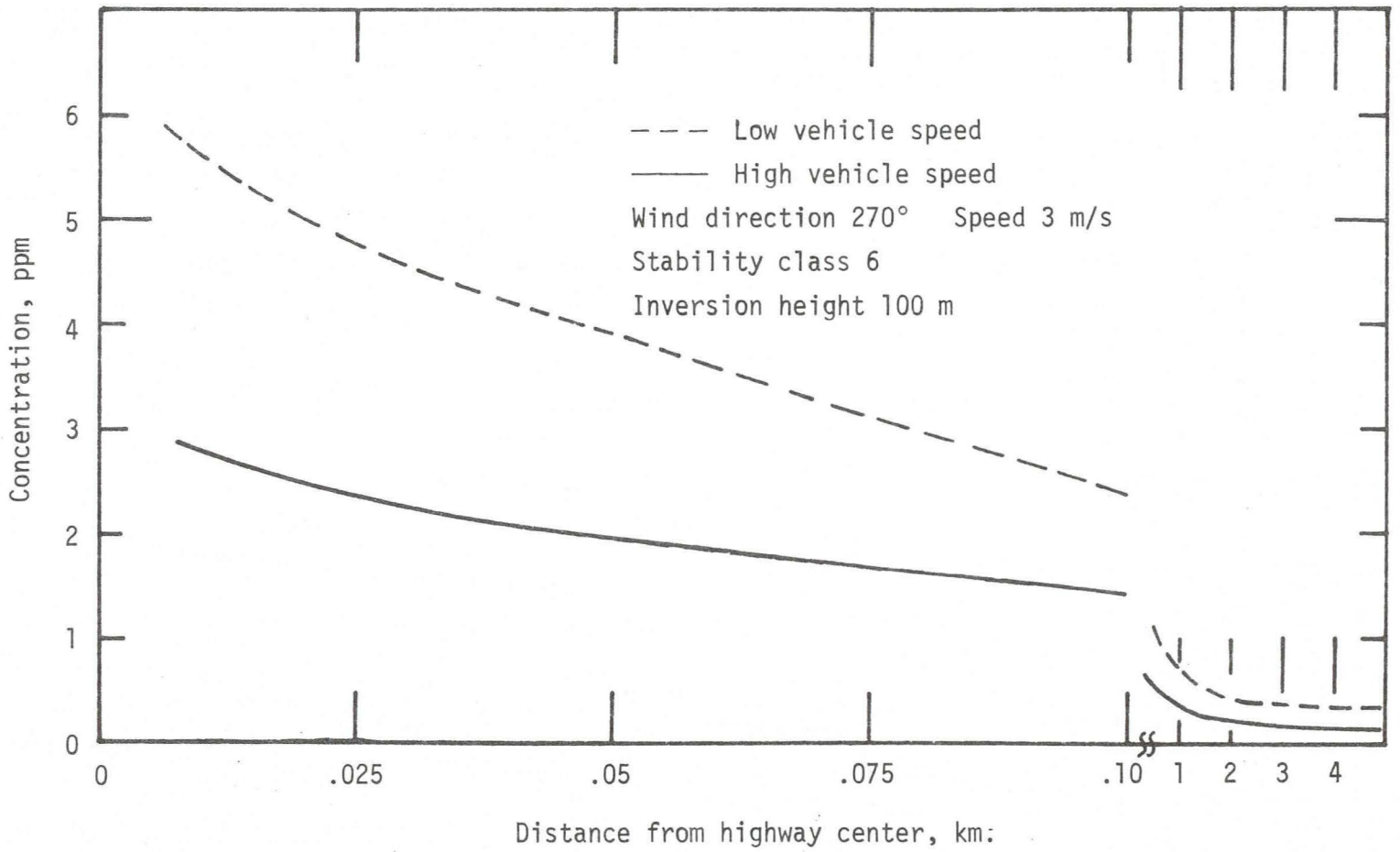

Fig. 4. Program HIWAY results for high wind speed, low inversion height case, one traffic lane.

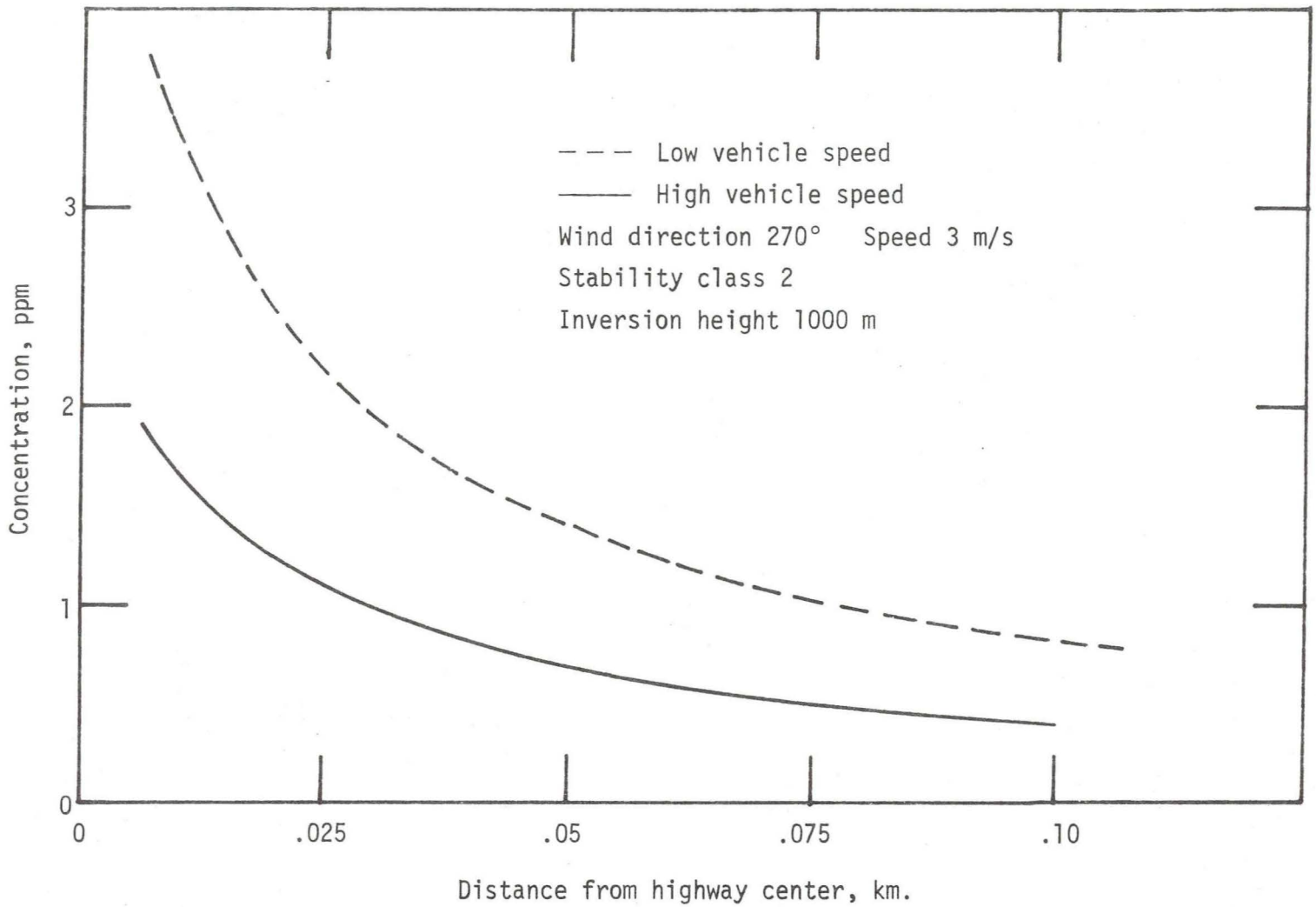

Fig. 5. Program HIWAY results for high wind speed, high inversion height case, one traffic lane.

Visibility

Reductions in visibility can result from emissions of particulates, nitrogen oxides and aerosol forming chemicals. In this report we limit the discussion to nitrogen oxides. Discussions of current practice on the estimation of visibility reduction by particulates can be found in the environmental impact statements for proposed coal fired power plants in the Rocky Mountain Region.

We consider the NO_x emissions from a large coal fired power plant of approximately 750 grams/sec. For the meteorological conditions: wind speed 4 m/sec, sunny day, and a 1500 meter high inversion base, the ground level concentrations can be estimated using a Gaussian plume model. The effective emission height is 150 meters. Estimates of the NO_x concentrations were made using Turners[3] methods. Then the visibility can be calculated using methods reviewed by Robinson[4] and Middleton[5]. We consider the horizon sky and an observer looking at the highest ground level concentration of the plume. This concentration is 0.74 ppm.

The ratio of scattered luminance with NO_2 to that without is

$$\frac{B_S}{B_{S_0}} = b/(b + k' c)$$

where b is the scattering coefficient, k', the extinction coefficient of NO_2 and c, the concentration. Figure 6 shows the results for visibilities without NO_2 of 10, 5, 3 and one mile. These curves indicate that a brown layer will be seen on the horizon from almost any distance. If we proceed further from the source and similarly examine the luminance we obtain Figure 7 for 5 km from the source. It is clear that the plume will be

visible when skies are clear for a considerable distance.

There will also be a reduction in visibility along the plume line. As an example at the two plume locations used above, one km and 5 km, Figure 8 shows the visibility reduction as a function of wave length for a target distance of two miles. The reduction is probably not significant beyond 30 km.

The more significant criteria would be the plume visibility on the horizon for these meteorological conditions. If we assume a reduction to 70% at 4000 Å is visible to the eye then the plume is visible as a 30 km line when the visibility is 70 miles. Figure 9 shows the plume length (30% reduction at 4000 Å) as a function of visibility.

This example was chosen to illustrate typical early morning northern Arizona conditions of visibility and atmospheric stability. Other examples can be calculated using the same procedures and the data given in the references.

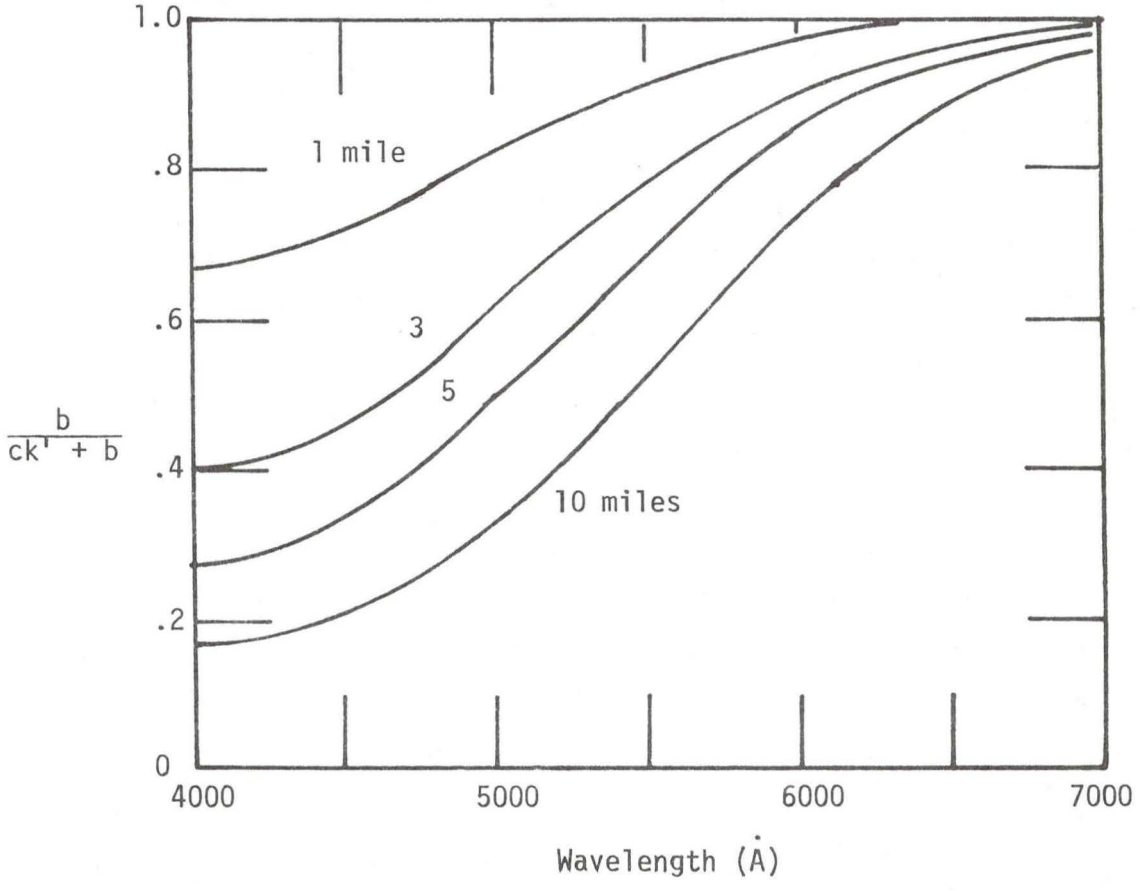

Fig. 6. Relative Intensity of Illumination from the Horizon Sky when NO_2 is 0.74ppm. Each curve represents a different visibility.

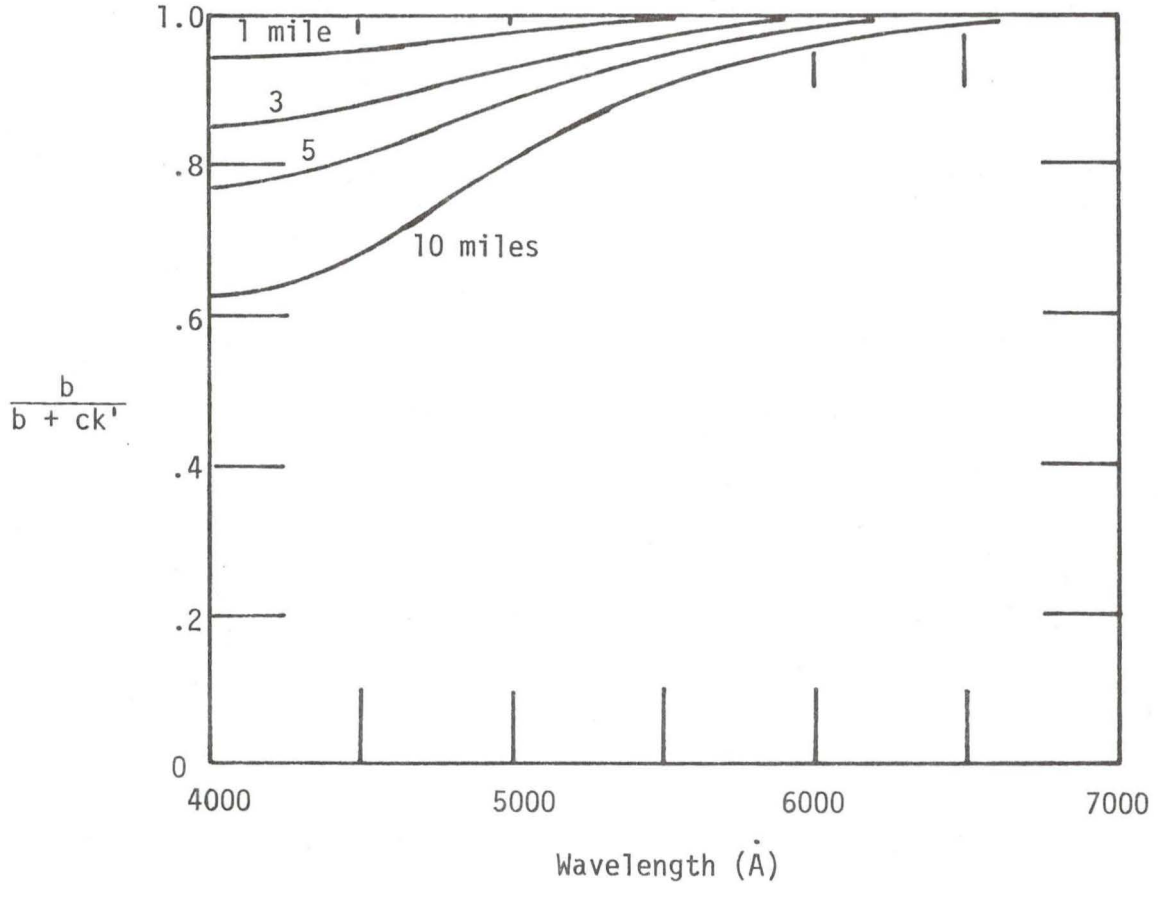

Fig. 7. Relative intensity of illumination from the Horizon Sky 5 km. from source.

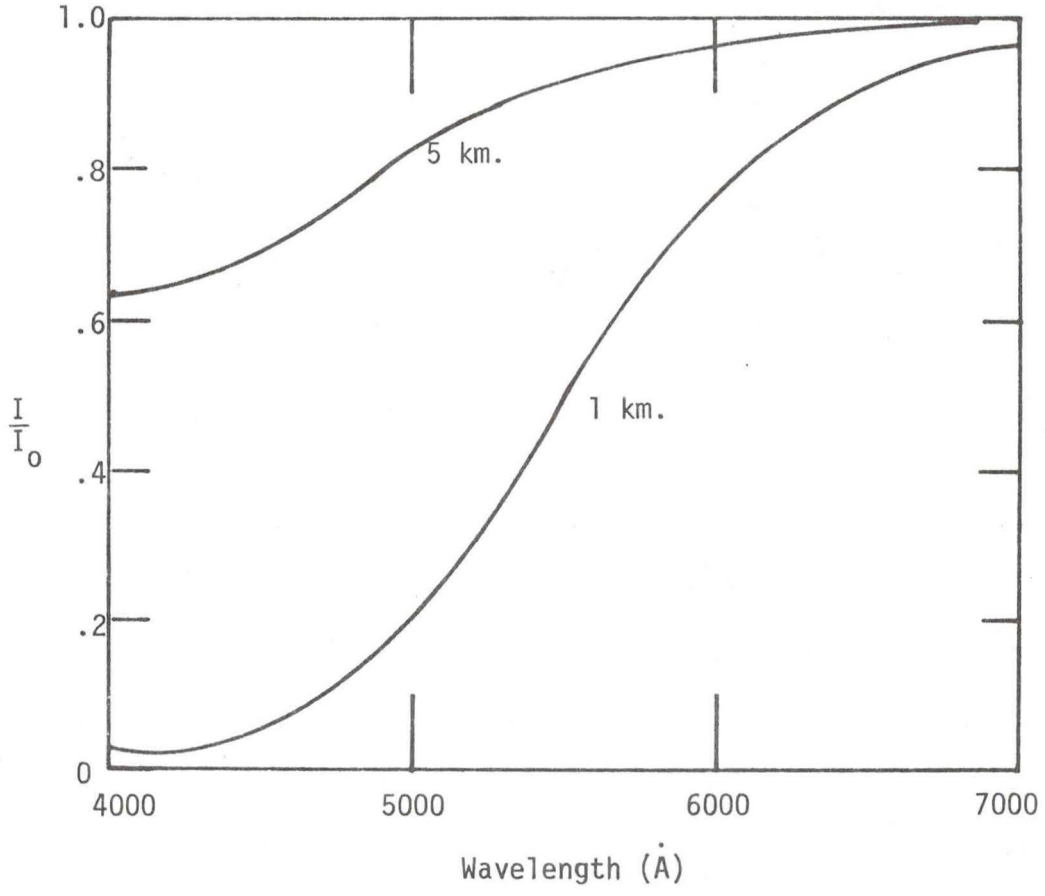

Fig. 8. Intensity of Illumination from a target as a function of NO_2 concentration relative to the intensity when NO_2 is zero. Target distances are one and 5 km. with the NO_2 representative of the plume at that distance.

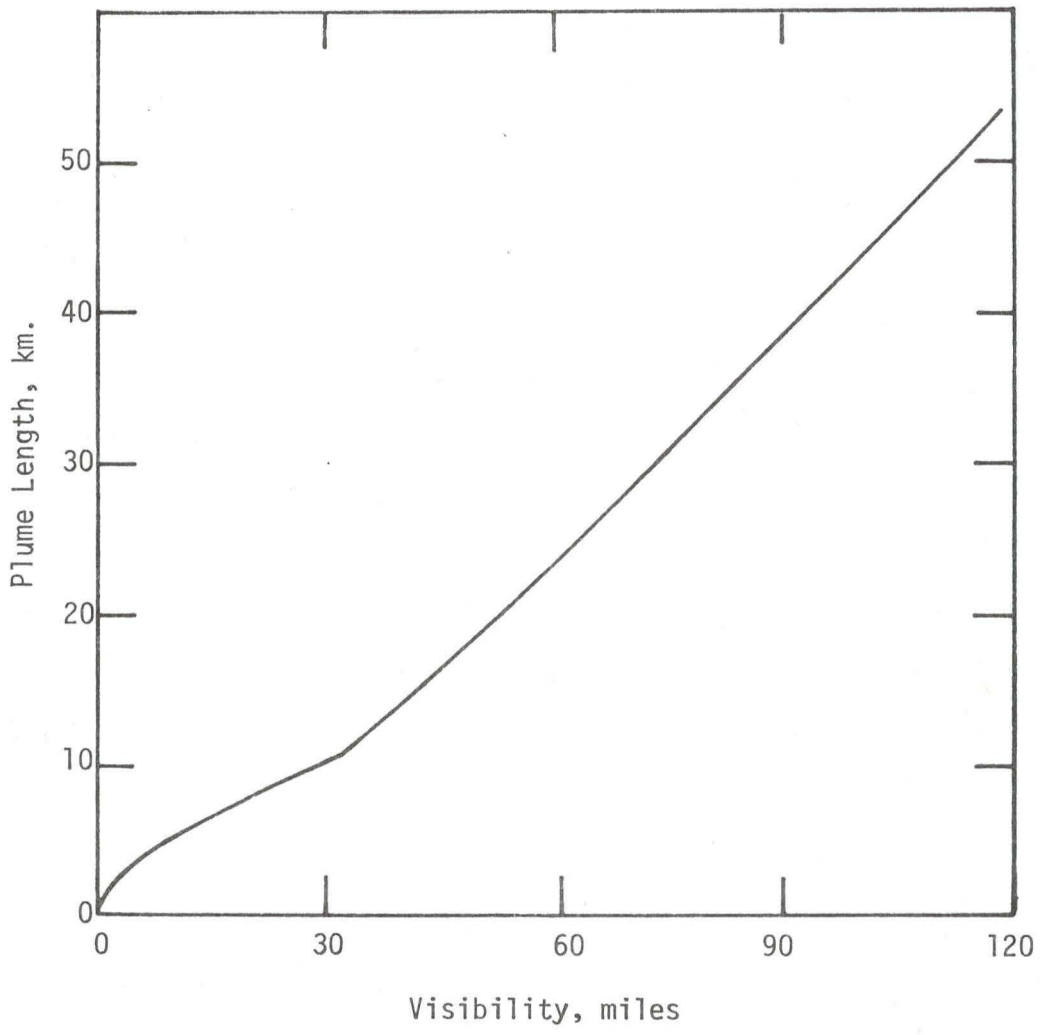

Fig. 9. Length of plume visible to an observer at the limit of visibility for the sample plume and atmospheric conditions.

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1. Zimmerman, John R., and Thompson Roger S. User's Guide for HIWAY, A Highway Air Pollution Model. U. S. Environmental Protection Agency. Research Triangle Park, North Carolina. Program Element 1AA009. February 1975.

2. Michael Duncan, "Validness Evaluations for two Air Pollutant Dispersion Models." Paper for CEE 567 Air Pollution, Arizona State University, Tempe, Arizona May 1976

3. D. Bruce Turner, "Workbook of Atmospheric Dispersion Estimates." U. S. Environmental Protection Agency AP-26 Office of Air Programs North Carolina 1970.

4. Elmer Robinson, Chapter 11, Effect on the Physical Properties of the Atmosphere in Stern ed. Air Pollution Vol. 1. Academic Press New York 1968.

5. W. E. Knowles Middleton, "Vision through the Atmosphere," U. Toronto Press 1952.